



Construction Industry Institute®

Information Integration to Improve Capital Project Performance

William J. O'Brien, P.E., Ph.D.

James T. O'Connor, P.E., Ph.D.

Youngcheol Kang, P.E., Ph.D.

The University of Texas at Austin

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by

William J. O'Brien, P.E., Ph.D.

James T. O'Connor, P.E., Ph.D.

Youngcheol Kang, P.E., Ph.D.

The University of Texas at Austin

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The University of Texas at Austin

Under the Guidance of
CII Research Team 258
Information Integration to Improve Capital Project Performance

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Contents

Chapter 1: Introduction	1
Chapter 2: Research Methodology.....	4
2.1 Research Team Formation and Alignment.....	5
2.2 Review of Literature and Team Experience.....	6
2.3 Analysis of Related CII Benchmarking Data	6
2.4 Information Integration Case Studies.....	7
2.5 Information Integration Maturity Models	8
2.6 Integration Opportunity Assessment and Tool	9
2.7 Application / Validation of Tools.....	11
2.8 IOP Assessment Process Model and Preparation of Presentation & Report.....	14
Chapter 3: An Information Integration Maturity Model for Capital Projects	16
3.1 Introduction	16
3.2 Literature Review – Maturity Models.....	17
3.3 Capital Projects Information Integration Maturity Model	19
3.3.1 Generation Process	19
3.3.2 General Maturity Model	20
3.3.3 Dimensions of the General Model.....	21
3.3.4 Capital Projects Business Function Maturity Model.....	25
3.4 A Maturity Model View of Industry Benchmarking Data	26
3.5 Applying the Maturity Model	29
3.5.1 Sample Application of the Maturity Model for Review of IOP Portfolio Plans	31
3.5.2 Applying the MM to Case Studies	32
3.6 Conclusions	37
Chapter 4: IOP Tool: Assessing the Benefits and Hindrances of Information Integration Opportunities.....	38
4.1 Introduction	38

4.2 Integration Opportunity Assessment Tool (IOP Tool).....	39
4.3 Validation	44
4.4 Applications of the IOP Tool	47
4.4.1 Hindrance Mitigation Planning	48
4.4.2 Comparative Analysis.....	49
4.4.3 Alignment among Business Partners.....	50
4.5 Discussion	52
4.6 Conclusions	54
Chapter 5: Analysis of Information Integration Benefit Drivers and Implementation Hindrances.....	55
5.1 Introduction	55
5.2 Literature Review	56
5.2.1 Market and Legal Factors	56
5.2.2 Organization and Processes Factors	57
5.2.3 People-related Factors	58
5.3 Research Objectives and Methodology.....	58
5.4 Importance Scores	60
5.5 Results from 16 Information Integration Test Cases	68
5.6 Conclusions	79
Chapter 6: Conclusions	80
6.1 Maturity Model	80
6.2 IOP Assessment Tool	81
6.3 Integration Drivers and Hindrances	82

Appendix A: Maturity Model	83
Appendix B: Integration Opportunity Tool	103
REFERENCES.....	114

List of Tables

Table 1: Research Team Members	5
Table 2: Respondent Answer Translation.....	10
Table 3: Weight Translation	10
Table 4: Weight Translation	12
Table 5: Number of samples for each function group applied to maturity model.....	13
Table 6: Cases applied to the IOP Tool	14
Table 7: Capital Project Information Integration Maturity Model	22
Table 8: Excerpt of Detailed Maturity Model for FEED Business Function	26
Table 9: CII Benchmarking and Metrics Data for Project Technology Use and Integration	27
Table 10: Analysis of case studies applied to the maturity model.....	35
Table 11. Respondent Answer Translation.....	42
Table 12: Integration Cases Applied to the IOP Tool.....	45
Table 13: List of Benefit Drivers and Importance Scores	61
Table 14: List of Hindrances and Importance Scores	65
Table 15: Description of Test Cases	69
Table 16: Responses from the 16 Test Cases for Benefit Drivers	71
Table 17: Responses from the 16 Test Cases for Hindrances.....	75

List of Figures

Figure 1: Research Methodology of RT258	4
Figure 2: Evaluating IOP Tool Assessment Results	11
Figure 3: TUI Median Values and Inter-quartile Range	28
Figure 4: Example of a Company Assessment across Multiple Functions.....	29
Figure 5: Integration Opportunity Assessment Process – Maturity Model through IOP Tool....	30
Figure 6: IOP Tool Structure	40
Figure 7: Example of Questions in the IOP Tool	41
Figure 8: IOP Tool Output.....	42
Figure 9: Evaluating IOP Tool Assessment Results	44
Figure 10: Application of Actual Integration Cases to the IOP Tool	47

Chapter 1: Introduction

CII Research Team (RT) 258 was broadly chartered to help CII member companies improve their use of information integration on capital projects. Information integration is a broad topic that encompasses people, technology and work processes. RT 258 has adopted the following definition of capital project information integration: “The sharing of information among project participants to support effective execution. Information integration is achieved with systems, work processes, and organizations that support the seamless exchange of and access to data.” As such, information integration is not just ‘information technology’ or ‘IT’ but is about supporting business processes and transactions across project participants.

The capital projects industry has many opportunities to improve information integration performance. The literature is replete with implementation examples – for example, 3D/4D CAD implementations (Hartmann, et al., 2008, Koo and Fischer, 2000, Staub-French and Khanzode, 2007), engineering analyses support by integrated databases (Miyatake and Kangari, 1993, Ahmed, et al., 2003), lifecycle uses of integrated information (Goedert and Meadati, 2008, Eastman, et al., 2008), etc. Firms have numerous opportunities to use integrated information to improve current work processes or implement new ones. However, identifying and prioritizing information integration opportunities are challenging tasks for firms. With respect to generating ideas about what should be done, there are many sources -- for example, case studies of specific successes publicized in trade journals, capabilities offered by technology vendors, grassroots ideas within the organization, etc. There are also visions for the future state of industry performance that have an associated technical development path (for example, the Capital Projects Technology Roadmap developed by FIATECH, www.fiatech.org). It is difficult for firms to systematically collect ideas from these sources and relate them to current capabilities, as well as define an investment path that makes sense in the corporate context.

As such, the research team conducted its research to both assess the current state of information integration in the capital projects industry as well as develop mechanisms to move forward. These efforts are expressed through development of a Capital Projects Information Integration Maturity Model, an Integration Opportunity Assessment Tool, a set of case studies of

successful information integration, and various reviews of the literature and CII benchmarking and metrics data related to technology use and integration. The sum of this material is published in this document as well as in the associated research summary (RS 258-1) and implementation resource (IR 258-2, volumes 1 and 2). IR 258-2 volume 2 contains the set of case studies that are of interest to practitioners as well as researchers. This research report describes the overall path of the research as well as specific aspects of development and validation of the tools. It does not duplicate the implementation resource and practitioners are directed to those publications.

The topic of information integration is a rich one that proved a source of many fertile discussions and reviews within the research team. The organization of this research report reflects this richness. Rather than following a traditional outline of literature review, methodology, data and analysis chapters, this report consists of four chapters beyond this brief introduction:

- Chapter 2 provides a comprehensive review of the team's efforts over the two year study. It describes the overall research methodology of the research team and details links between the various activities of the team.
- Chapter 3 describes the development and application (validation) of the Capital Projects Information Integration Maturity Model. The maturity model exists in two forms: First, a general maturity model, which is intended to broadly capture the state of the industry with respect to work processes and associated investments in technologies and people. Second, a highly detailed maturity model across eight capital project functions that builds from the general model to help firms assess their capabilities within these common functions, as well as identify specific opportunities for improvement. The maturity model is compared to industry benchmarking data and applied to several case studies of information integration success undertaken by CII member companies.
- Chapter 4 outlines the Information Integration Opportunity Assessment Tool (IOP Tool), which can help firms better evaluate implementation drivers and hindrances that may affect a specific tool. The tool walks users through 37 benefit driver questions and 34 implementation hindrance questions and provides a score that summarizes relative driver/hindrance weights. The score is placed on a grid Companion detail about the tool

is provided in IR 258-2 volume 1. This chapter focuses on development efforts and validation tool by application to 16 test cases independently identified as implementation successes/limited successes.

- Chapter 5 further analyzes the data from the 16 test cases used to validate the IOP Tool to better characterize which drivers/hindrances actively affect integration implementation efforts. The tool compares importance scores determined by the research team with rankings from assessments from the 16 cases. These allow comprehensive review of which drivers/hindrances are most important and most consistently experienced by industry.

Chapters three through five are semi-independent and describe different tools and analyses that contribute to the academic in industry understanding of information integration. Literature review and conclusions are contained with each chapter. Collectively, the work advances the state of knowledge in significant ways, adding considerable detail to the literature.

Chapter 2: Research Methodology

This chapter presents the research methodology followed by RT 258. Figure 1 provides an overview of the approach. The reviews, analyses, and tools generated by the research team are described in more detail in the following chapters. This chapter shows the relation between the range of activities of the research team.

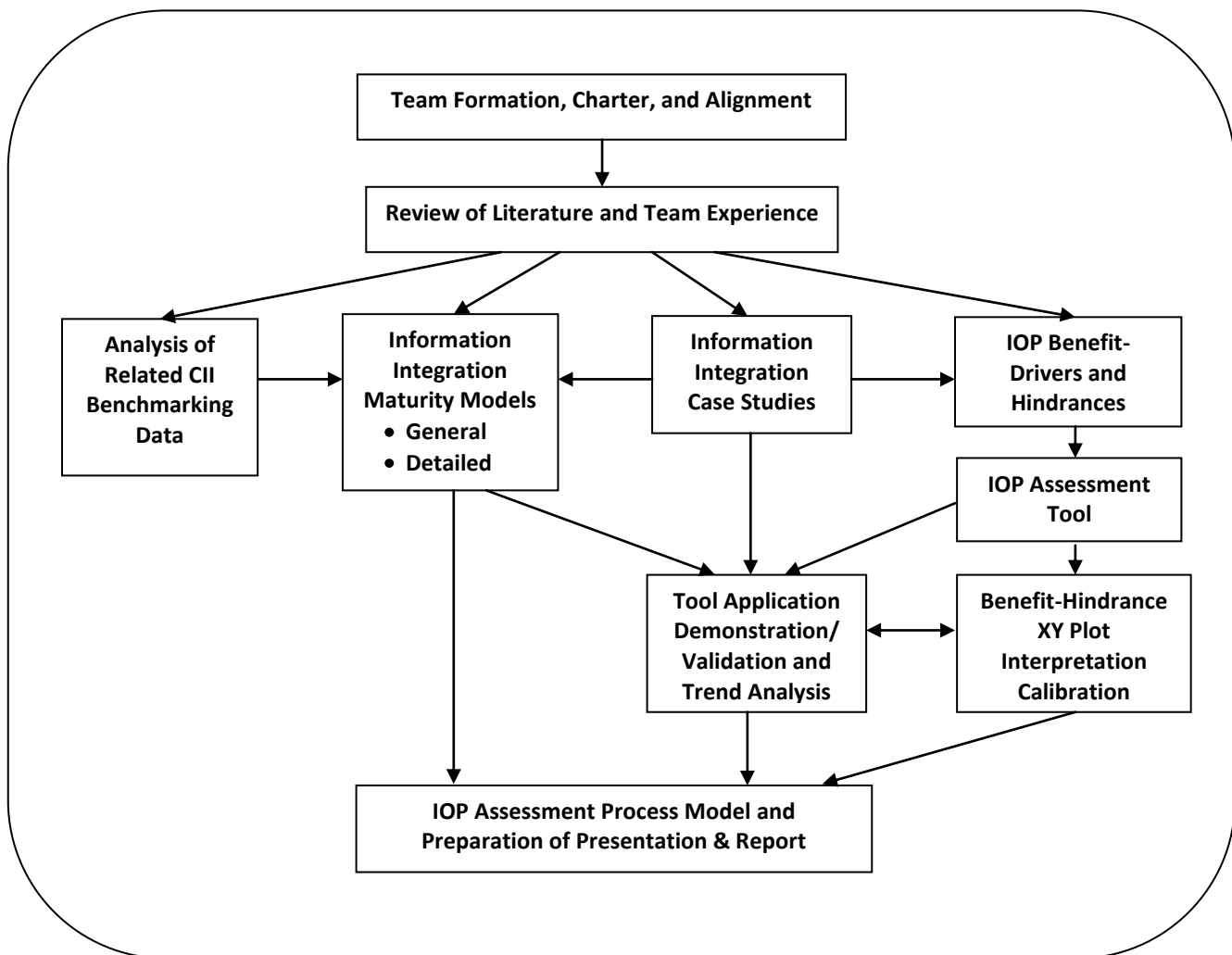


Figure 1: Research Methodology of RT258

2.1 Research Team Formation and Alignment

The Research Team was comprised of the 15 CII members from owner, contractor and academic organizations (listed below in Table 1). With over 25 years of average experience in the capital project industry, team members had expertise in project management, project controls, and project information management.

Table 1: Research Team Members

Name	Company	Role
Hugh (Tad) L. Fry, III	Anheuser-Busch InBev	Owner
Dan W. Hodges, Intel	Intel Corporation	Owner
Paul Hughes	Marathon Oil Company	Owner
Youngcheol Kang	UT Austin	Academia
Sujal Lagowala	Bechtel Corporation	Contractor
Kathryn L. Lust	Mustang	Contractor
William J. O'Brien	UT Austin	Academia
James T. O'Connor	UT Austin	Academia
Diane F. Odom	Jacobs	Contractor
Mike T. Oswalt	Fluor Corporation	Contractor
Gabriel Saenz	Shaw	Contractor
Garrett D. Sever	DuPont	Owner
Bruce A. Strupp	CH2M HILL	Contractor
James Thorne	Worley Parsons	Contractor
Matthew E. Wheelis	Autodesk, Inc.	Vendor

From the kick-off meeting onward, RT members broadly discussed issues pertaining to information integration in capital projects. Specific topics of interest included tools and applications associated with 3D CAD, SAP, vendor data integration, along with challenges with different types of stakeholders.

The RT members exchanged their ideas on challenges, solutions, and needs for the research. Also, in this process, RT members started characterizing integration attributes into three categories: institutional (legal/market), organizational/process, and people.

The team's objectives as stated in its Charter were as follows:

- Understand the current status of information integration in the capital projects industry.

- Provide a structured process and tools to help companies assess their information integration efforts and a path forward.

2.2 *Review of Literature and Team Experience*

A literature review was initiated by the researchers to establish and share the intellectual underpinnings of the topic. A wide variety of academic journals, government publications, and industry publications were examined for salient issues and notable developments. Topics of particular interest in both the project management and business management literature included systems integration, format of maturity models, IT application case studies, and implementation of change, among others.

Several RT members proceeded to share their personal experience with information and organizational integration. Focused discussions ensued pertaining to project information managers, information flow, work processes, IT tools, interoperability best practices, and related performance benchmarking. Subsequent, iterative literature reviews followed as new topics of interest emerged. These iterative discussions helped the team determine the focus and scope of the maturity model and IOP Tool.

2.3 *Analysis of Related CII Benchmarking Data*

Fortunate for the RT, CII has been gathering project benchmarking data on the subject of information integration for approximately two years. The resulting database of project inputs pertaining to information integration and project outputs pertaining to performance offered some new and potentially unique insights into the topic. The goal of this activity was to ascertain, in a quantitative way, the current state of information integration in the capital projects industry.

CII's Technology Use and Integration (TUI) questionnaire was designed to measure the degree of technology use. It has 50 work processes categorized in six groups. For each work process, the respondent is asked to evaluate the degree of automation, internal integration, and external integration according to a 0 to 4 scale where 0 is none/no use of automation/integration, 2 is moderate use, and 4 is extensive or seamless use. Ten TUI metrics are developed; six indices representing the level of technology use for each work process group, three indices for

automation and internal and external integration, and one overall index consolidating all scores for all types of technologies across all work processes surveyed.

The available data consisted of 58 project data from Owners and 24 from Contractors. All projects were completed in 2007 and 2008 and are reported in 2008/early 2009. Regarding data analysis, the research team calculated median values and inter-quartile ranges for TUI indices.

2.4 Information Integration Case Studies

The purpose of documenting case studies was to understand the current status of information integration in the practicing capital projects industry. Selected team members' success cases on information integration implementation were documented, exchanged, discussed, and refined. An outline of questions was developed at the outset to help maintain consistency and completeness in case study content.

This effort helped team members to have a more general or holistic view about information integration. Case study content elements included identification of information integration opportunities, comments on how they were implemented in real-organization and real-project contexts, what the associated implementation problems were, and how they were resolved, among other issues. Subsequent to the first draft of the case studies, and after progress had been made on both the Maturity Model and the IOP Tool (both of which are discussed in detail below), the case studies were supplemented with analysis content pertaining to the following:

- Use of Maturity Model
- Use of IOP Tool
 - Hindrance Mitigation
 - Comparative Analysis
 - Consideration of Inter-organizational Integration Opportunity
- Use of Maturity Model and IOP Tool in different phases

This activity helped the RT to recognize the importance of 1) Understanding the current status of their processes in terms of information integration; and 2) Formal assessment of specific integration opportunities.

2.5 *Information Integration Maturity Models*

Based on the previous steps, the academic team members prepared a draft of a maturity model tool for assessing the status of current integration functions and processes within the broader context of integration maturity or extent of development.

An existing maturity model from the IT sector was examined for its structure and usability within the RT's context. The model has three explicit levels and was attractive to the team as a starting point. Perhaps more important, the maturity model had both a business demand for services as well as a supply of those services provided by corporate information technology capabilities. This explicit description of business demand and service supply better addressed the need to map work process capabilities with technical infrastructure. While extremely useful as a model, the maturity model developed by the consultant had a focus on general business information technology services and lacked any customization to the capital projects industry. Building from its general structure and informed by the many other examples of maturity models in existence, the team undertook construction of a capital projects information integration maturity model essentially from scratch. These efforts generated both forms of the Maturity Model described below.

With the knowledge obtained from the previous step, the RT258 members had a brainstorming and discussion process to develop a maturity model for capital projects industry. For this process, they identified the characteristics of processes or organizations' attitude toward processes differentiating the level of maturity (i.e., view of information management, project IS strategy, work processes & deliverables, etc.). Also, they developed descriptions about each level in terms of various characteristics they identified.

In parallel with development of general Maturity Model, the research team developed a detailed Maturity Model. To accomplish this, the team was sub-divided into groups of three. For the eight work function groups, each sub-group set up deliverables for the function groups

and developed descriptions about how the deliverables are delivered in the different maturity levels.

The eight function groups were assigned to the three sub-groups. After each sub-group developed the descriptions, they were reviewed by other sub-groups. After this, academic team members polished the descriptions. The detailed Maturity Model was finalized after a final review by RT members.

2.6 *Integration Opportunity Assessment and Tool*

A primary objective of the RT was to develop a tool that would assist capital project organizations (both Owners and Contractors) in assessing information integration opportunities. No such tool had existed prior to this development and project-oriented organizations were sorely in need of such assistance. The effort resulted in the Integration Opportunity (IOP) Assessment Tool. Additional commentary here further explains how the tool came about.

The RT258 team members brainstormed issues influencing information integration and identified more than 70 factors driving and/or restricting information integration implementation. Factors were identified as either “benefit drivers” or “implementation hindrances”. Factors were also categorized as either belonging to the categories of market/legal, organizational and process, or people/roles/training. Overall, 37 benefit drivers and 34 hindrances were identified by the research team.

The team then configured the IOP benefit drivers and hindrances into the structured IOP Assessment Tool. The benefit drivers and hindrances were transformed into user queries or questions and each question in the IOP Tool was iteratively reviewed and revised by the research team members. In addition, the questions were externally reviewed by a project IT team that was not otherwise represented on the RT.

For the subject (described) integration opportunity, the IOP Tool assesses quantitatively both the likely degree of benefit and the level of hindrances likely to restrict or constrain implementation of the subject integration opportunity. The quantitative values (benefit driver score and hindrance score) are calculated using the input from users together with importance weights for each question that were determined through a survey of the RT. The optional

responses for the benefit driver assessments and the associated quantitative scale are shown in Table 2.

Table 2: Respondent Answer Translation

	Benefit Driver Extent				
Respondent Answer	High (Yes)	Medium High	Medium Low	Low	NONE (No)
Translated Score	4	3	2	1	0

In addition to the respondents' assessment of benefit driver extent, the IOP Tool employs scaled weights to reflect differential importance for each driver and hindrance. In survey mode, each team member was asked to assess the general or typical importance of each driver and hindrance in the context of capital project-related IOPs. Weights for the questions not answered ("No response") or answered "NA/UNK" (Not applicable or Unknown) were removed from the averaging computations. Thus, weights were calculated only with assertive responses. In the weighting process there were four choices from which the team members could select. Each choice was transferred to a numeric value as shown in Table 3.

Table 3: Weight Translation

Choice	Score	
	Benefit Drivers	Hindrances
High	9	8
Medium	6	5
Low	3	2
Depends	6	5

Different values were assigned to benefit drivers and hindrances so as to reflect the distance between the values and a zero weighting. From the two scores (respondents' answers and weights), the benefit driver and hindrance scores are calculated as follows.

From the equation above, through the IOP Tool a score between 0 and 100% can be determined for each benefit driver and hindrance. A higher score indicates greater or more

extreme IOP benefit or IOP implementation hindrance. The scores help users evaluate the likely benefits against the likely implementation challenges resulting from hindrances.

In order to facilitate interpretation of IOP Tool results, the RT developed a plot of Hindrance Score (X axis) vs. Benefit Driver Score (Y axis) shown in Figure 2. Opportunities in the green zone (as illustrated in the figure below) are more likely to be successfully implemented than those in the yellow or red zones. Industry team members discussed the figure and determined the slopes and locations of the lines differentiating the zones and words in the plot.

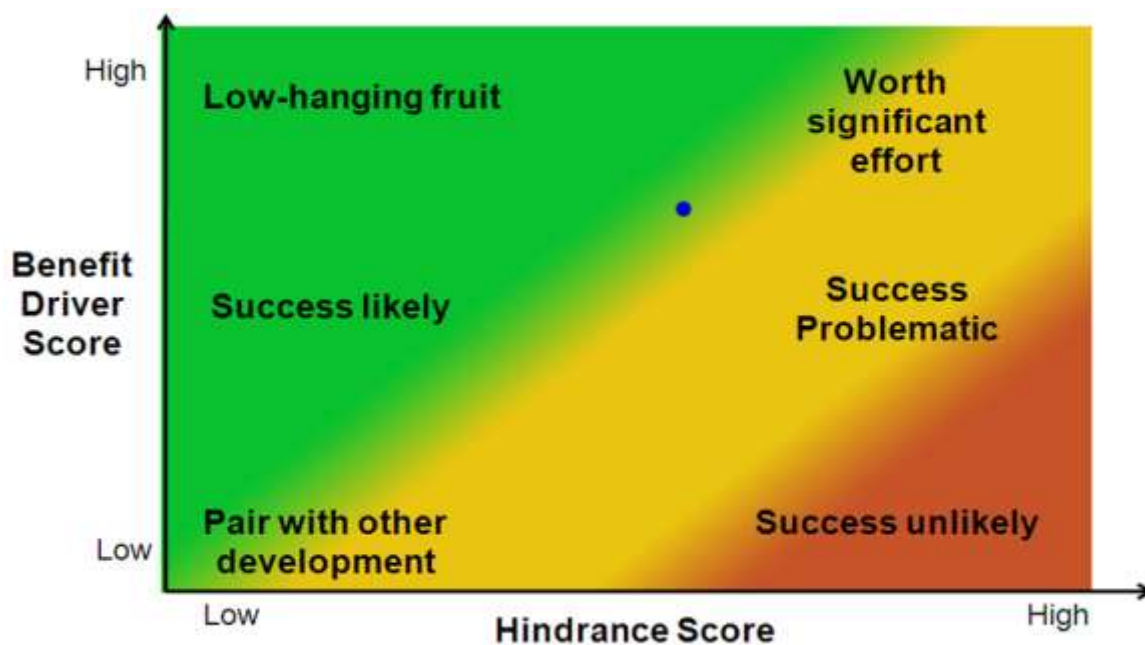


Figure 2: Evaluating IOP Tool Assessment Results

A total of 16 different integration opportunity cases were applied to the IOP Tool and plotted on the X-Y plot to the satisfaction of the RT. Thus, the plot has undergone a process of validation, as further described in the next section.

2.7 Application / Validation of Tools

The Maturity Model and the IOP Assessment Tool were demonstrated or tested in the context of many real-world IOP case studies. Methodology-related details of those demonstrations are further described here.

As indicated in Table 4, the Maturity Model was applied in eight different cases. First, interviews were conducted with the RT258 members who provided the case studies. During the interviews, the maturity levels both before and after IOP implementation were roughly estimated, but there was no validation of the MM assessments. However, the process and ease of assigning MM level was discussed within the RT, as was the value derived from such assessment.

In most cases, the maturity levels determined in the analyses generally apply only to the specific project process and/or project team under consideration, rather than at the organizational level. During the interviews, each maturity level was segregated into three sub-levels (i.e., high level 1, medium level 1, and low level 1). This was intended to differentiate processes within a given level vs. those IOPs in transition to another level. Detailed learnings from these demonstrations are presented in a subsequent chapter.

Table 4: Weight Translation

ID	Respondent Type	Description
Company A	Contractor	Vendor data integration with Engineering/Construction/Client Applications
Company B	Contractor	Estimating integration with 3D models, material quantities, and takeoff from preliminary and actual design models
Company C	Owner	Integration using 3D model with spool drawings and BOM
Company D	Owner	Time and attendance gate log system integrated with billing system
Company E	Contractor	Progress measurement system integration information about work scope, work package including man-hour budgets
Company F	Contractor	Integration for managing key project performance data
Company G	Owner	Integrated project execution management system for better collaboration with various stakeholders
Company H	Contractor	Integration between material management system and ERP

As explained later, the Maturity Model is organized by Function Group. The sample size for each function group is shown in the table below. Overall, eight integration cases generated 32 data points, which means each integration case involved an average of 4 work function groups.

Table 5: Number of samples for each function group applied to maturity Model

Function Group	Sample Size	Function Group	Sample Size
Front End Planning	2	Startup & Turnover	2
Conceptual Engineering/FEED	4	Procurement	4
Detailed Engineering	6	Project Controls	8
Construction	4	Operations & Maintenance	2
Overall: 32			

A total of 10 companies applied the IOP Tool in 16 different case studies, as shown in Table 6. RT258 members and their internal and external colleagues conducted the assessments with the IOP Tool. Follow-up interviews were conducted as needed for clarifications or to address any inconsistencies. Detailed learnings from these demonstrations are addressed in Chapter 4.

Table 6: Cases applied to the IOP Tool

Resp. Type	Point Label	Description
Cont.	Company A	Vendor data integration with Engineering/Construction/Client Applications
	Company A Limited	Vendor 3D model integration
Cont.	Company B	Estimating integration with 3D models, material quantities, and takeoff
Owner	Company C	Integration using 3D model with spool drawings and BOM
Owner	Company D	Time and attendance gate log system integrated with billing system
Cont.	Company E	Progress measurement system integration information about work scope, work package
	Company E Limited	Construction schedule information integration (limited success)
Cont.	Company F-1	Document management system integration (F-1)
	Company F-2	Schedule information integration (F-2)
	Company F-3	P&ID integration (F-3)
Owner	Company G Phase I	Project Execution Management System Phase I
	Company G Phase II	Project Execution Management System Phase II
Cont.	Contractor H	Integration between material management system and ERP
	Company H External	Data sheet and drawing representation interchange (External)
Cont.	Company I	3D smart model
Vendor	Company J External	Data sheet and drawing representation interchange (External)

2.8 IOP Assessment Process Model and Preparation of Presentation & Report

From the MM and IOP tools developed by RT258, a process for assessing integration opportunities was developed and refined by the team. Academic team members had several meetings and teleconferences to discuss how to structure the IR report and what content should be included in the report. Once the structure was finalized, some of industry team members were assigned to provide or assist with write-ups. RT members drafted the plenary and implementation session presentation slide sets for the annual conference.

This section describes the process by which a CII member company can deploy the Capital Projects Information Integration Maturity Model and Integration Opportunity Assessment Tool to systematically assess its current status, identify a portfolio of integration opportunities, and select specific opportunities for deployment.

Chapter 3: An Information Integration Maturity Model for Capital Projects

This chapter describes a Capital Projects Information Integration Maturity Model (maturity model) that can be used by companies to assess their current state of information integration practice. The maturity model can also be used to derive a portfolio of integration opportunities to aid firms in making a systematic plan for further investment in information integration. The maturity model exists in two forms: A general model that describes three levels of information integration that broadly characterize firms' experience. This general model is supplemented with a detailed model that can be used by firms to review in detail their information integration deployment plans as well as identify new opportunities. The maturity model has been validated through application to several cases as well as through comparison with CII Benchmarking and Metrics data for Technology Use and Integration.

3.1 Introduction

CII RT 258 was broadly chartered to review and help improve implementation of information integration within the capital projects industry. One difficulty that became apparent in RT 258's review of current information integration practices and challenges is that there is not a one-size-fits-all solution for the industry. Even companies with similar capabilities and market niches (for example, large industrial EPC firms) have unique sets of work processes, internal organizations, cultures, and legacy investments in information systems. Essentially every company is starting from a different point, and while they can make similar investments in information integration, those investments need to be customized for successful implementation. This makes it very hard for companies to simply take and adapt an implementation success at another company for its own use. For example, one company's success at exchanging three-dimensional (3-D) model data across internal units may stem from previous investments in internal standardization and corporate work processes that clearly specify handoff points

between functional groups. Another company that has not made these preliminary investments may not be able to benefit from 3-D technologies to the same extent.

While firms must make independent and specific assessments of information integration opportunities, the research team believed that it would be useful for firms to have a tool that would help them assess their current capabilities in a manner that would allow comparison to other firms/efforts in a broader context and also help a firm set expectations and an informed development path. This need motivated RT 258's development of a capital project information integration maturity model. It is the goal of a maturity model to define concrete steps by which a firm progresses in its capabilities. The maturity model accomplishes this by defining common states within the industry; a firm can map its current capabilities to these common states.

3.2 Literature Review – Maturity Models

A key starting reference for maturity models is the CMMI (Capability Maturity Model Integration) developed by the Software Engineering Institute at Carnegie Mellon University (SEI, 2001). The CMMI contains a very detailed specification for assessing the maturity of work processes across five discrete levels or stages: Initial, Repeatable, Defined, Managed, and Optimizing. These levels are meant to be progressive, and have associated with them highly detailed assessments. However, these stages and assessments are meant to be applied to very specific work processes and are not easily scaled to a broader assessment.

Many other maturity models build in some way from the five CMMI levels and some of these more intuitively capture broad business states. One consulting firm describes five states of information technology services as awareness, committed, proactive, service aligned, business partnership; another variation is chaotic, reactive, proactive, service, value (Fenn, 2009). Others have adapted the CMMI concepts to other sectors, for example supply chain management: (Lockamy and McCormack, 2004) identify stages of supply chain process maturity as ad hoc, defined, linked, integrated, and extended where the earlier stages refer to unorganized activities and the later stages refer to progressively more organized and strategically directed activities. Concurrent with these stages is a prediction that associated work processes and work process outcomes become more efficient, effective, stable, and certain. Similarly, Vaidyanathan and Howell (2007) identified a five stage model relating to construction supply chains closely

following CMMI levels, although they suggest that at each level maturity can be assessed in multiple dimensions: process, technology, strategy, and value. However, beyond specification of the framework, the authors' model has not been further developed or applied.

Others have proposed adapting CMMI to project management. Fincher and Levin (1997) proposed a translation of the five CMMI levels to project management. Ibbs and Kwak (2000) and Kwak and Ibbs (2002) significantly extended the work of Fincher and Levin and developed a maturity model rating scheme with a range of detailed questions regarding project management capabilities. Their work did not find the details of the CMMI useful, rejecting its emphasis on technology and also expressing a desire for a quantitative assessment. Kwak and Ibbs (2000) developed a 161 question survey where each question has five answers relating to each maturity level. Their questions are focused on contractors and relate closely to project capabilities such as project planning and tracking as well as organizational capabilities. They find that companies have a range of maturities and these maturities vary by type of capability being measured (2000). Such a range of assessment was viewed by the industry team members as more reflective of reality than a single measure.

While learning from the CMMI and related models, the RT 258 team made a determination that these models were too complicated to allow firms to make a rapid and useful assessment of their overall status. In particular, five levels were seen as somewhat difficult to parse and that wider bands or levels would allow for more ease of identification. As an alternative starting point, the team chose a "Business-IT Maturity Model" proposed by an information technology consultant that has three explicit levels, delineated as business efficiency, business effectiveness, and business transformation (Merlyn, 2007). Each level has a distinct set of business practices and cultural norms that distinguish it from the other levels and also make it difficult to move from one level to the next without a coordinated change in both business practices and technical capabilities. This distinction was seen as important by the RT 258 team as it reflects the observations that firms have unique sets of capabilities that may be reflected by different maturity levels. This maturity model was attractive to the team as a starting point as its three levels appeared to better match states within the capital projects industry than the five in other assessments. Perhaps more important, the maturity model described by the consultant represented both a business demand for services as well as a supply of those services provided by

corporate information technology capabilities. This explicit description of business demand and service supply addressed the need to map work process capabilities with technical infrastructure.

Merlyn's (2007) three level model is supported by the work of Rapp (2002) who delineated a three level strategic framework for IT. Rapp suggested three progressive levels where IT is first seen as a cost center (level 1), then a strategic asset (level 2), and finally as fully integrated into the corporate business planning and execution processes (level 3). Rapp's work is addressed to a general business audience and is not specific to the capital projects industry. He also takes a more strategic framework following Porter's competitive strategy framework (Porter, 1998, Porter, 1998) and discusses the use of asset specific investments in IT to create market barriers, including the adoption of proprietary standards. Such specific recommendations do not seem compatible with the fragmented capital projects industry that is currently seeking adoption of uniform data standards (Taylor, 2007, Back and Moreau, 2001, El-Gohary, 2009). However, the three-level framework as well as the progression from level to level is seen as useful by the research team.

3.3 Capital Projects Information Integration Maturity Model

3.3.1 Generation process

While extremely useful as a starting point, the maturity models developed by Merlyn (2007) and Rapp (2002) have a focus on general business information technology services and lacked any customization to the capital projects industry. Building from its general structure and informed by the many other examples of maturity models in existence the team undertook construction of a capital projects information integration maturity model essentially from scratch. As described in Chapter 2, the team took into account the literature review as well as details from a set of case studies of information integration success (published as IR258-2 Volume 2) to gain a better understanding of the current state of information integration in the capital projects industry. They then developed by a General and detailed Capital Projects Business Function in an iterative fashion through a series of face-to-face team meetings and conference calls. For the detailed model, work was done in sub-groups and later revisited by the larger team. Both versions of the maturity model are described below and the complete text is found in Appendix A.

3.3.2 General Maturity Model

The general Maturity Model is meant to be a brief overview capturing the essence of each of the three levels and their corresponding state. While variations in practice are large both within and across companies, each of the three levels of the Maturity Model is meant to capture a state that is broadly identifiable and applicable to CII member companies. Interestingly, while CII generally categorizes firms as belonging to owners or contractors and treats each separately, the research team believed the maturity model was applicable to each class of firm and purposely did not make a distinction. The project management functions within owners are broadly similar to contractors and the assessment and recommendations offered by the maturity model should be broadly applicable to both classes of firms. Each level describes both work processes as well as accompanying information systems. Each level builds from the capabilities of the previous level and as such, companies are expected to progress up each level in a stepwise fashion. We briefly characterize each level as:

Level 1: Business Efficiency

- Low use of integrated applications
- Focus on silo efficiency
- Limited understanding of integration opportunities

Level 2: Business Effectiveness

- Integration focus on internal processes
- Focus on speed of established processes, reliability of execution

Level 3: Business Transformation

- Seamless exchange of data internally and externally
- Focus on high value project execution
 - speed across value chain
 - leverage skills of distributed team

A level 1 company has limited use of integrated applications and primarily focuses on efficiency within existing silos. Information integration is not well understood or strongly supported amongst the functional units. A level 2 company has moved away from silo efficiency and is realizing – at least in part – efficiencies of information integration internally across business functions. A level 3 company has successfully implemented a wide range of

technologies supporting information integration and has defined work processes that support seamless exchange of information. A salient aspect of a level 3 company is an ability to seamlessly exchange information externally with key partners. A level 3 company can then focus on rapid project execution that leverages the skills of a broad team. Note that level 3 is meant to be aspirational – the best companies today are only emerging level 3.

3.3.3 Dimensions of the General Model

As shown in Table 7, there are five dimensions the research team identified to characterize different maturity levels. All of them are key determinants of returns on information integration implementation. The dimensions were determined based on the existing maturity models and team members' experience. However, those can be also supported by academic literature.

Table 7: Capital Project Information Integration Maturity Model

CII RT 258 – Capital Project Information Integration Maturity Model			
	Level 1: Business Efficiency	Level 2: Business Effectiveness	Level 3: Business Transformation
View of Info. Mgmt.	The potential of information management is not understood and has few champions. Information integration is not a priority within the corporate vision.	Information management is seen as part of the business solution – being both an opportunity and a challenge.	Information management is fully integrated with the business strategy and is seen as invaluable. It enables true differentiation between you and the competition.
Project IS Strategy	Project information system plans are developed on an ad hoc basis – most often driven by customer demands.	Project information system plans are routinely developed and updated. These often seek to overcome data exchange issues across project organizational units.	Problems with data management and data exchange are minimal and project-specific systems planning focuses more on advancing strategic business needs and interests.
Work Processes & Deliverables	Work processes and deliverables are DOCUMENT-centric. Many processes are not well defined and involve large amounts of tacit, ill-structured information. Considerable time is spent gathering data. System applications mostly support individuals or isolated work groups, and lend little reinforcement to work processes.	Work processes and deliverables are a blend of DOCUMENT- and DATA-centric. Internal processes are mostly well defined and standardized and many internal information transfers support intelligent data exchange. However, external information exchange is not seamless, and seeking data from external sources can be time-consuming.	Work processes and deliverables are DATA/ OBJECT-centric with a focus on efficient exchange with external entities. Information gathering is rapid, allowing more time for productive analyses. System applications are highly interoperable and support flexible, adaptable, integrated business processes. Business processes represent best-in-class use of corporate knowledge and information systems.
Organization Culture & Performance Metrics	Most work occurs inside silos with minimal collaboration. “Over the wall” and “first in-first out” approaches are common. The culture embraces silos. Performance metrics are silo-oriented. For example, engineering performance is measured in sheets of drawings.	Organizational boundaries are clearly defined and most integration is internally focused. Many silos have been bridged, but some still exist. Overcoming these is viewed as an opportunity for advancement. Integrated approaches are valued. Performance metrics are a mix of silo- and team-oriented. Engineering progress, for example, can be measured by the amount and quality of data generated.	Silos are no longer a barrier to information exchange and the organization has seamless boundaries between work functions and major project stakeholders. Silos that do exist remain for business, not technical reasons. Integrated approaches and associated benefits are ingrained in the culture. Performance metrics focus on business performance, customer satisfaction and team success.
Data Standards	The data standards applied are few in number and offer only limited benefit. Data consistency is not present across silos. The value of data standards is not well understood.	The adoption of data standards is largely accomplished with consistent representation of data across internal stakeholders. The adoption of industry standards (e.g., IFC, ISO 15926) is under consideration.	Industry data standards have been adopted wherever they’re justified by life-cycle benefits. Efforts have been invested to ensure that most legacy applications are integrated with industry standards.

The first two dimensions – view of information management and project information system (IS) strategy – are interrelated each other. Organizations in lower maturity levels may achieve no or very limited benefits from information integration. Thus they may not see much value in information management and IS strategy is far from their business strategy. In the business literature, alignment between business strategy and IS strategy has been reported as one important factor determining the size of returns on IT investment. The alignment has been generally thought to have substantial impacts on organizational performance as well (Chan, et al., 1997, Sabherwal, et al., 2001, Brynjolfsson and Hitt, 1996). Oh and Pinsonneault (2007) empirically found that alignment between business strategy and IS strategy on cost reduction was negatively associated with organization expense. In the capital projects industry, the importance of information management strategy has been recognized (Back and Moreau, 2001, Erdogan, et al., 2008) but it tends to be apart from business strategy, which becomes one major barrier to justifying IT investments (Love and Irani, 2004). Overall, organizations integrating their IS strategy to business strategy are more likely to succeed in information integration implementation. Also, once they achieve significant benefits, they may change the view of information management and see it as an important source of competitiveness or business solution.

The third dimension is work processes and deliverables. Research team members and practitioners widely using information integration applications have constantly asserted that old processes are one major hindrance for IT adoption and achieving benefits out of IT and should be improved. While there have been needs from practitioners for business process reengineering (BPR) according to IT use, BPR in the organizational level has little been investigated in academia (Erdogan, et al., 2008). According to Lee (2004), BPR can be classified into two categories: BPR in physical flow and information flow. The third dimension in the maturity model is involved in information flow in processes. If information required for a process is tacit, ill-defined, and document-centric, information may not be able to flow rapidly and this will lead poor process performance. No matter what IT application is implemented in the process, returns of the application to the process will be very limited.

The fourth dimension is organization culture and performance metrics. Many studies stressed that organization culture related with the level of innovation encouragement and degree of cooperativeness is one key for successful implementation of information integration

(Mitropoulos and Tatum, 2000, Orlikowski, 1996, Wade and Hulland, 2004). However, adversarial culture in the construction industry is one big barrier restricting collaboration and data sharing within and between organizations (Anumba, et al., 2000), leading delay of information flow. Such culture may embrace silos and reflect narrowly scoped performance metrics simply measuring process-level performance rather than business performance.

The fifth dimension is data standards. Capital projects industry is notoriously fragmented and processes by various stakeholders are heavily interdependent. In such environments, role of data standards becomes more important as information exchange is crucial for successful process delivery. In terms of level of interdependency among processes, Gattiker and Goodhue (2005) argued that more interdependent processes have greater benefits from enterprise resource planning (ERP) which enables more information integration and data standards. The maturity model takes this aspect into account. Organizations using more data standards are more likely to have more accurate and timely information exchange and this will contribute to higher returns.

Related to the relatively low use of information integration technologies, RT 258 team members observe a range of work processes that show limited integration. For many companies, internal silos continue to be the predominant characteristic by which work is performed. Some integration happens within functional silos, but communication across silos tends to be “over the wall”; associated performance metrics tend to benefit silo efficiency over project efficiency. Firms that exhibit higher degrees of information integration tend to have addressed barriers between key internal silos (for example, design to procurement) and have integrated work processes and investments in supporting information systems.

In general, firms are expected to progress up the maturity model in steps from one level to the next. There are considerable investments in technology, work processes, and corporate training (and perhaps culture) to move up a level. Moving up two levels – from level one to level three – in one step is generally viewed by the research team as too difficult to achieve and likely to result in implementation problems, failure to achieve expected results, etc. Indeed, one important contribution of the Maturity Model is to dimension the steps between performance levels; this can provide both a path for planning performance improvements as well as a check on expectations that may be driven purely from a technology standpoint. For example, existing commercial software from major vendors increasingly provide technical support for level three performance, but a level one firm shouldn’t expect to be able to reap all of that performance

without several intermediate steps. The detailed model described below helps to describe such intermediate steps for business functions and work processes in each function.

3.3.4 Capital Projects Business Function Maturity Model

Building from the general model, a considerably more detailed Capital Project Business Function Maturity Model (detailed Maturity Model) is used for more detailed assessment. (The detailed Maturity Model is found in Appendix A) It follows the general model by having three equivalent levels, but adds detail for several business functions: Front-End Planning (FEP), Front End Engineering and Design (FEED), Detailed Engineering, Procurement, Project Controls (Controls), Construction, Startup, and Operations and Maintenance (O&M). These functions are typical capital project functions performed by both owners and contractors. While owners and contractors do vary to some extent in their roles and work processes in each of these phases, the research team did not think it necessary to separate the detailed maturity model for owners and contractors. Rather, the detailed model provides several ideas for work process capabilities at each level within each business function that should broadly apply to firms in the capital project industry regardless of type or discipline.

For each business function, the detailed Maturity Model lists several common deliverables accomplished during that function. Each deliverable has examples of work process capabilities for each of the three levels. For example, Table 8 provides an excerpt from the detailed Maturity Model for the FEED phase and deliverables Project Specification and Standards. (This is but one of eight deliverables detailed for FEED.) Each business function has a similar range of detail for several deliverables. As can be seen from the example in Table 8, the detail while considerable remains broadly applicable. Each firm can use the detail provided as a starting point for assessment and elaboration for their specific situation. The description of the work process capabilities can be used either to assess a company's performance level for the function or help to identify specific capabilities for improvement. With respect to the example in Table 8, a firm might see its current capability as level 1 and express a desire to move to level 2. Level 3 could be considered a longer-term goal.

Table 8: Excerpt of Detailed Maturity Model for FEED Business Function

<u>Deliverable</u>	<u>Level I</u> <u>Business Efficiency</u>	<u>Level 2</u> <u>Business Effectiveness</u>	<u>Level 3</u> <u>Business Transformation</u>
Project Specifications & Standards	▪ Electronic documents that contain inaccessible data and that are not linked to either source documents or project design drawings	▪ E-specs are linked to the project WBS & 3D CAD design elements ▪ Standard packaged designs are provided by major equipment vendors in e-format	▪ BIM model includes specs & standards that are fully linked to building codes, QA/QC controls, procurement functions, cost estimating, site activity scheduling, ... ▪ Spec. & standard updating is automatically prompted by primary source entities

3.4 A maturity model view of industry benchmarking data

CII collects a range of industry benchmarking data from member company projects. Data collected for each project includes general information about the project, basic project performance characteristics, and a range of data relating to productivity and practice use. One practice use that CII collects relates to Technology Use and Integration (TUI). Within the main benchmarking project questionnaire, the TUI questionnaire asks questions about technology use across 50 work processes categorized in six groups. For each work process, the respondent is asked to evaluate the degree of automation, internal integration, and external integration according to a 0 to 4 scale where 0 is none/no use of automation/integration, 2 is moderate use, and 4 is extensive or seamless use. 10 TUI metrics are developed; six indices representing the level of technology use for each work process group, three indices for automation and internal and external integration, and one overall index consolidating all scores for all types of technologies across all work processes surveyed.

Table 9 summarizes the median values for the ten TUI indices. It also presents the 1st and 3rd quartile values of the technology use groups (i.e., the table presents the median and inter-quartile range). Note that per CII convention, data from owner and contractor companies are reported separately. Data is from 82 projects; 58 from owners and 24 from contractors. All projects were completed in 2007 and 2008 and are reported in 2008/early 2009.

Table 9: CII Benchmarking and Metrics Data for Project Technology Use and Integration

TUI Index	Owner (n=58)			Contractor (n=24)		
	Median	25%	75%	Median	25%	75%
Overall	1.83	1.31	2.10	2.07	1.81	2.61
Project Management	1.67	1.14	2.29	2.29	1.93	2.67
Front End Planning	1.76	1.20	2.15	1.90	1.63	2.00
Detail Design	2.00	1.44	2.25	2.19	1.44	2.96
Procurement	1.79	1.06	2.15	2.25	1.50	3.33
Construction	1.63	1.22	2.00	2.33	1.48	2.36
Startup/Commissioning	1.73	1.31	2.01	2.00	1.00	2.33
Automation	1.86	1.60	2.21	2.66	1.80	2.67
Internal Integration	1.83	1.32	2.09	2.19	1.83	3.00
External Integration	1.83	1.26	2.17	2.27	0.60	2.77

Note: Average results posted where 0 = none, 2 = moderate, and 4 = extensive use of automation/integration.

As shown in the table, respondent medians are generally below 2, which indicates the level of technology use and integration in the capital projects industry is moderate. The table also shows 25% and 75% quartile values to give a sense of the variance across CII member companies. With few exceptions, even the 75% percentile is close to 2 or a moderate level of technology and integration use. These results are consistent with the discussion and case studies of the RT 258 team, which found many technical successes but general information integration performance lower than desired or possible.

The results of Table 9 are shown graphically in Figure 3, which shows the median values as the center dot and the bars show the inter-quartile range between the 25th and 75th percentile performers. For all indices, contractors' median values are higher than owners', indicating contractors use technology and integration more than owners. This statement can also be supported by the quartile ranges. Except for Front End Planning, contractors' scores are greater than owners' scores. On the other hand, owners' technology use is generally more consistent, shown by a smaller inter-quartile range. Contractors have more variance. Among the six work process groups, Detail Design and Procurement mean values are the highest for both owners and contractors, perhaps reflecting more relative investment in technology and integration (and also perhaps reflecting areas of higher risk to projects that supports investment).

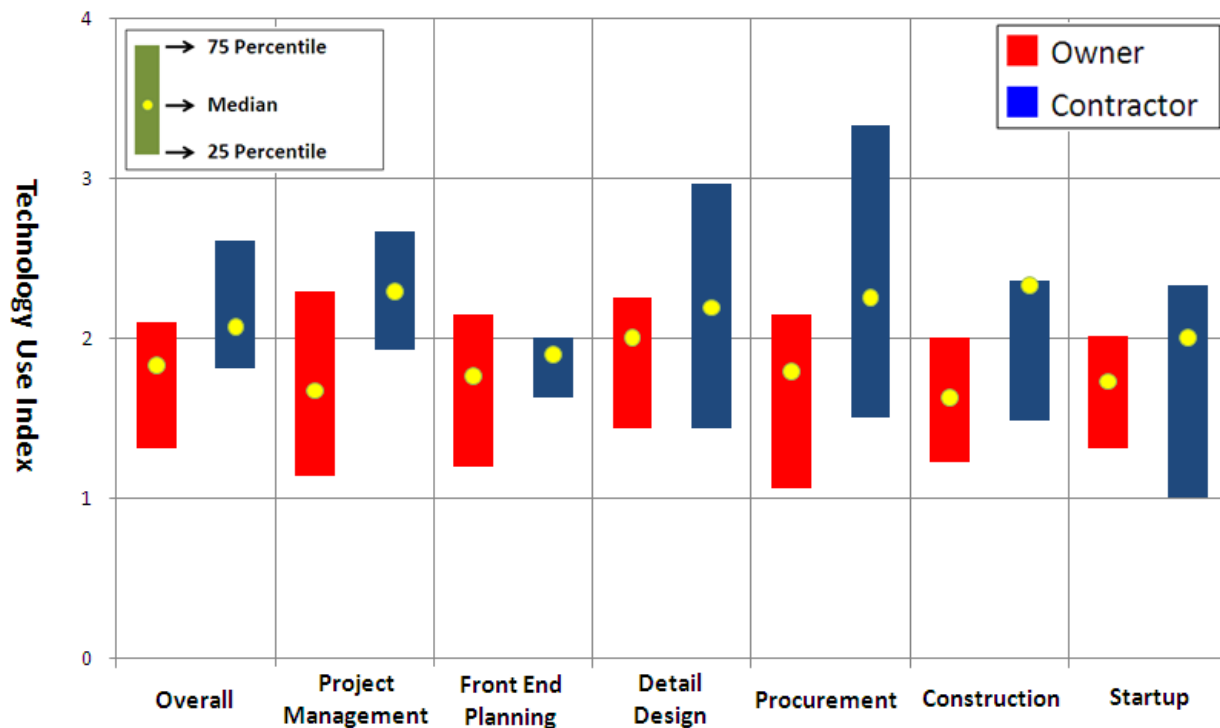


Figure 3: TUI Median Values and Inter-Quartile Range

Prior to reviewing the TUI data, the CII RT 258 industry team members thought that most of the industry was at various stages of level 1 or level 2 (business efficiency to business effectiveness) with only emerging applications of level 3 (business transformation). The TUI data confirm these experiential observations, finding that much of the industry is at or below moderate use of integration/automation technologies. Some areas such as detail design and procurement (Figure 3) are starting to see higher levels of technology use. These generally correspond to areas with significant development of technologies (e.g., CAD for design) and clear needs for cross firm communication (e.g., procurement). These maturity model level 3 or business transformation applications are just emerging; no project rates itself as a 4 or extensive on the TUI scale and published case studies show such potentially transformative technologies and processes are novel within the industry (Hartmann, et al., 2008, Froese, 2010, Chung, 2008). As such, the maturity model helps to dimension the TUI data and adds context to the data with respect to performance and expectations around processes.

The TUI data also indicate that there are different performance levels not just across firms, but also across typical business functions such as procurement and front end planning.

This provides conceptual validation of the detailed or business function maturity model which provides specific parameters for the three levels across business functions. A firm's rating at different levels can be visualized as shown in Figure 4, which depicts a company that has achieved level 2 status in FEED and Detailed Engineering, but has level-one capabilities in the other functions. With reference to the example in Figure 4, the company might be described as a level one performer with emerging capabilities into level two. Alternately, personnel who primarily operate in the FEED and Detailed Engineering functions might describe the company as level 2 without understanding the limitations of the other functions.

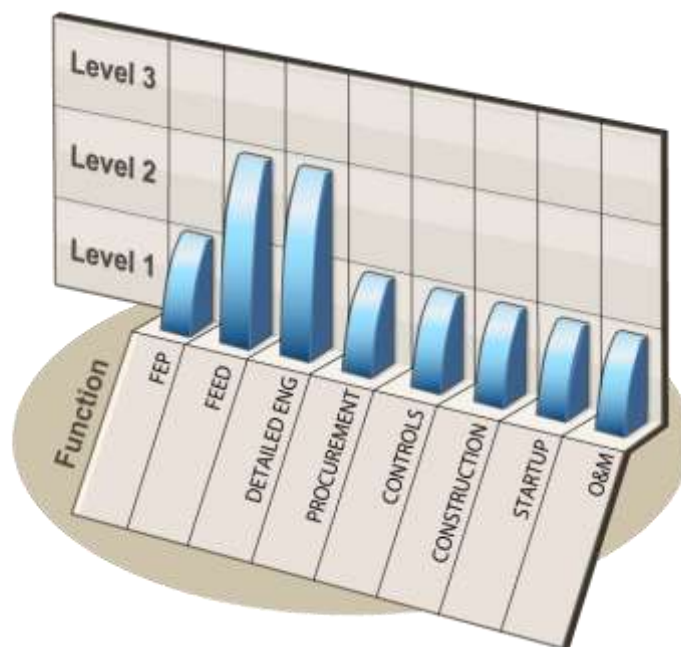


Figure 4: Example of a Company Assessment across Multiple Functions

3.5 Applying the Maturity Model

As a statement of current practices and what should be, the maturity model in both forms cannot be validated in a statistical manner, but rather through acceptance and use. (Its application to interpreting the CII TUI data is a form of validation in this sense.) The team developed a process for applying the maturity model and subsequent integration opportunity assessment tool (IOP Tool) described in later chapters. This overall process is shown in Figure 5. The first set of activities concern use of the Maturity Model to status the organization, identify gaps, and detail a suite or portfolio of integration opportunities – IOPs. Once the portfolio of IOPs has been

created, each IOP should be evaluated using the integration opportunity assessment tool (IOP Tool). Once evaluated, high-value IOPs can be identified and undergo further, company specific analysis. Such more detailed analysis may uncover new benefit drivers or hindrances and the IOP Tool can be used to reassess the integration opportunity. Assessment and analysis can be used to support a deployment plan for the IOPs selected for implementation.

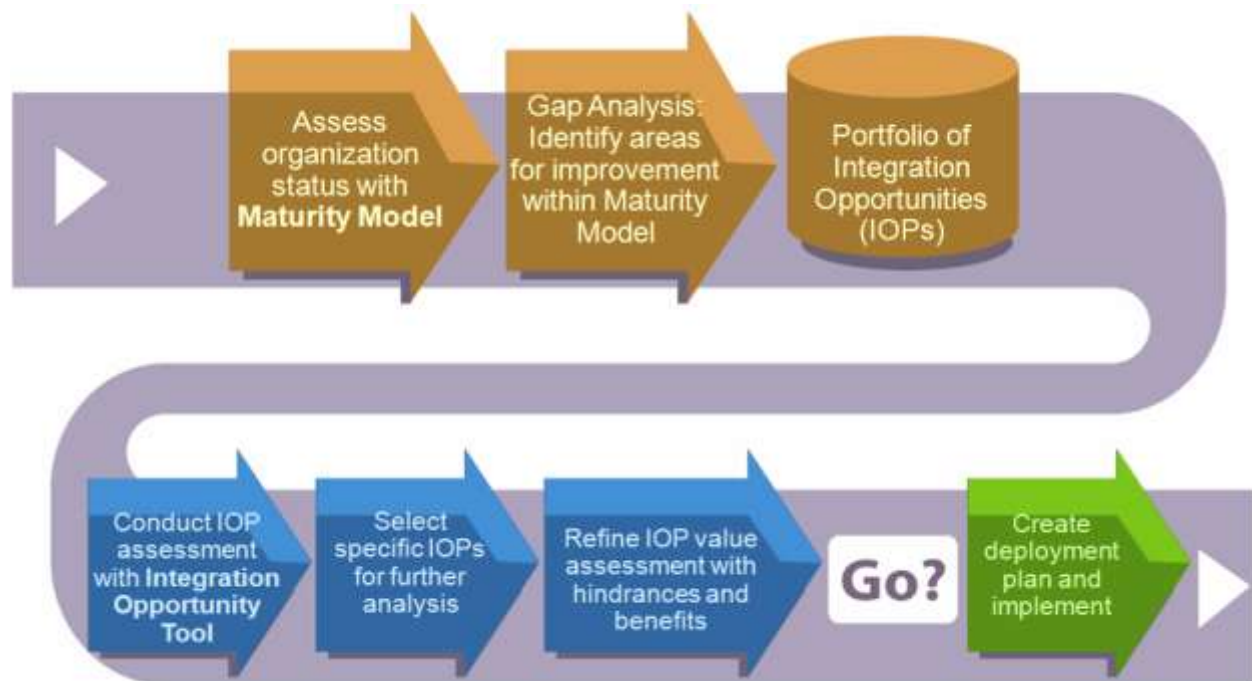


Figure 5: Integration Opportunity Assessment Process – Maturity Model through IOP Tool

There are three recommended steps in the process for use of the maturity model. The first step is assessment of the current state of information integration with the company. The goals of assessment are (1) to develop a shared understanding of the levels of the maturity model and their translation to a specific corporate context, and (2) develop a detailed assessment across eight capital project business functions -- Front-End Planning (FEP), Front End Engineering and Design (FEED), Detailed Engineering, Procurement, Project Controls (Controls), Construction, Startup, and Operations and Maintenance (O&M). The Maturity model is presented in two forms – a general or summary format and a detailed format with examples across the eight business functions (see Appendix A) – that directly support these two goals. At the end of the